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THE MEXICAN WHORLED MILKWEED (ASCLEPIAS MEXICANA AS A POISONOUS PLANT.

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CONTENTS.

INTRODUCTION.

Many of the milkweeds are said to have poisonous properties. Definite experiments, however, proving their toxic or nontoxic characteristics have been made in regard to only a few species. Reports by stockmen and others of the poisoning of livestock by these plants have been made from many parts of the Western States, and yet almost an equal number of reports have been made asserting that the plants are harmless. Generally speaking, the reports of harmful results have not indicated clearly what species of milkweed was supposed to be involved. For the most part the plants were not examined by botanists who could determine the species correctly. The United States Department of Agriculture, in making investigations of these cases, has frequently been very much in the dark as to the actual plant suspected and has been led to make experiments on plants which proved to be nontoxic so far as livestock are concerned.

Certain definite and rather startling results, however, have been obtained in the investigation of the whorled milkweeds. As shown in Bulletin 800 of the United States Department of Agriculture,

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Asclepias galioides, the whorled milkweed of Colorado, Utah, Arizona, and New Mexico, is one of the most poisonous of the weeds affecting our livestock, and under some circumstances causes very heavy losses. Especial interest, therefore, attaches to the other closely allied plants. The whorled milkweeds form a very distinct group of the milkweed family, *Asclepiadaceæ*, being easily recognized by the narrow leaves which are frequently arranged in a whorled manner.

The number of species of these plants depends upon the opinions of the botanists who study them, but for our purposes four may be recognized which have a fairly definite geographical range. The relationships of these species are briefly characterized by Eggleston in Bulletin 800, United States Department of Agriculture, pages 5 and 6: *Asclepias galioides* is found in Colorado, Utah, Arizona, and New Mexico, west of the Continental Divide, and so far as known does not extend west of Utah; *Asclepias pumila* grows in the plains east of the Rocky Mountains; *Asclepias verticillata* is found in the Mississippi Valley, and eastward; *Asclepias mexicana* is a western species, being especially abundant in California.

In Bulletin 942, United States Department of Agriculture, *Asclepias pumila* and *Asclepias verticillata* var. *geyeri* were shown to have properties similar to those of *Asclepias galioides*, but differing in degree. It is evidently a matter of considerable importance, as well as of interest, to find out definitely the character of *Asclepias mexicana*, which has been frequently reported in California as a sheep-poisoning plant, although published statements are very few.

Chesnut (1898) says that it is reported from California that sheep and calves were poisoned by eating the growing plant, and cows by eating hay containing it.

Pammel (1910) quotes the statement of Chesnut.

Jepson (1911) states that it is said to poison cattle.

Hall (1912) says:

> It is much dreaded by sheepmen on hot days, when they are obliged to drive their flocks over dry districts, where there is little other vegetation and no water. Under these conditions the sheep are tempted to eat the milkweed, which contains an active poison and causes many deaths. This is sometimes prevented by cutting the plants down a few days before the sheep are driven through, the object being to dry the herbage and so render it less tempting.

Hall and Yates (1915) speak of the three species, *Asclepias mexicana*, *Asclepias eriocarpa*, and *Asclepias speciosa*, as being equally poisonous, treat of their distribution, and give symptoms as reported to them. These symptoms do not correspond to those appearing in sheep poisoned by *Asclepias mexicana*. It may be noted, too, that the authors of this bulletin have not only failed to get any clear evidence of poisoning by *Asclepias speciosa*, but have also failed experimentally to poison animals by it.

Fleming (1920) gives the dosage by which experimental calves and sheep were poisoned.

Fleming and co-authors (1920) give a somewhat extended account of the plant, with a report of feeding experiments on cattle and sheep.

It seems probable from present investigations that many of the cases of poisoning attributed to *A. speciosa*, *A. eriocarpa*, and *A. fremonti* were really due to *A. mexicana*. No detailed experimental work, however, has been done on *A. eriocarpa* or *A. fremonti*.

DESCRIPTION OF ASCLEPIAS MEXICANA.[1]

The following is a technical description of the plant, *Asclepias mexicana* (see Pl. I), known as the Mexican whorled milkweed, also as the narrow-leaf milkweed. The stems are erect, single or several, often branching at base, woody at base, 1 to 6 feet high; main root horizontal, branching, producing adventitious buds; stems glabrous below, slightly short, hairy, and branching above; the leaves in whorls, 2 to 6, sometimes in axillary bundles, linear to narrowly lanceolate, short petioled, 2 to 6 inches long, 2 to 6 lines wide, often folding together, smooth, acute at both ends; flowers usually in corymbose terminal umbels, many-flowered, peduncles much shorter than leaves, and 2 to 3 times as long as the pedicels, which are surrounded by numerous narrow bracts; corymb and flowers short, soft, hairy; flowers greenish-white, sometimes purplish; calyx and corolla turned back after opening; calyx five-cut; corolla deeply five-cleft; crown of 5 hoods, hoods erect, open, containing a linear horn 2 or 3 times as long as the hood, and surrounding the column (united stamens) in which are the 2 ovaries, with slender styles, which unite to the single disklike stigma, the anthers adhering to the stigma and opening on the outside, thus compelling the use of insects or some other outside agency to transport the waxy mass of pollen to the stigma disk; pods from 2 to 3 inches long, smooth, narrow, splitting on the sides, seeds flat, reddish-brown, with a tuft of long hairs at summit. It flowers from June to August.

DISTRIBUTION AND HABITS OF ASCLEPIAS MEXICANA.

The plant ranges from Mexico northward through California, western Nevada, and southern Washington to eastern Idaho, as shown in figure 1.

For central California Jepson (1911) says, "Forming patches in dry ground, common and widely distributed in barren valley fields." It is also a foothill species; in speaking of Nevada M. E. Jones, in an unpublished note, states that it occurs in juniper and oak zones. For the range from northern California to Washington, Howell tells us that

[1] The description of the plant and the account of its distribution were prepared by W. W. Eggleston, of the Bureau of Plant Industry.

"it is found along streams." It follows the valley of the Columbia River and its tributaries into Idaho, where it is occasionally found at an altitude of 6,000 feet. It occurs on the Warner Mountains, Modoc County, Calif., at that altitude, but usually in other parts of the United States it is at much lower altitudes.

Like *A. galioides* it quite plainly thrives best in newly disturbed soil, but there is no evidence that it is spreading as a weed so rapidly as *A. galioides*. In comparison with *A. galioides* it is a larger plant, with wider leaves and flower clusters in a terminal corymb.

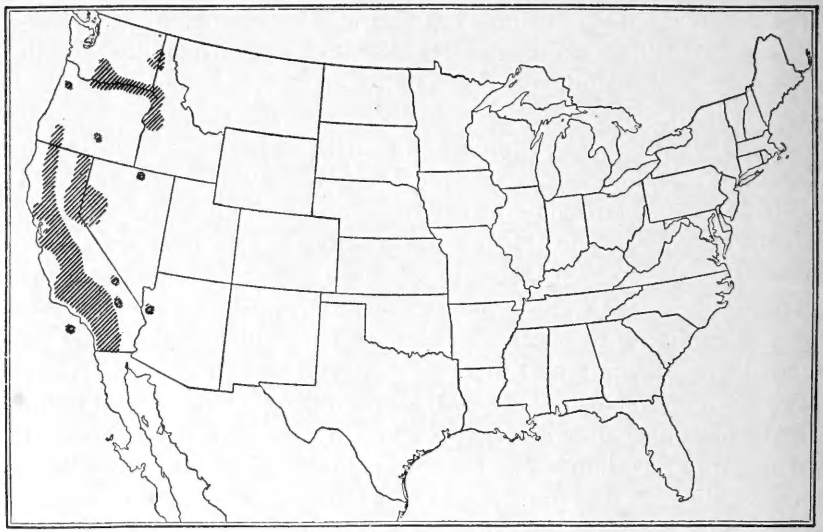

FIG. 1.—Distribtuion of *Asclepias mexicana* in the United States.

EXPERIMENTAL WORK.

During the summer of 1920, 19 feeding experiments with *Asclepias mexicana* were made. In all cases sheep were used, the material being fed with the balling gun. In 5 cases the whole top—leaves, stems, and flowers—was fed; in 5 other cases leaves and in 9 cases stems were used. The material was obtained through the kindness of Prof. H. M. Hall, of the Carnegie Institution, and was collected at Mount Diablo, Solano, Hollister, and between Newman and Dos Palos, all in California. While dried plant was fed, the dosage is given in terms of green plant for 100 pounds weight of sheep, 75 per cent being allowed for loss in drying.

In Table 1 the experiments with this plant are summarized.

ASCLEPIAS MEXICANA, SHOWING MANNER OF FLOWERING AND THE FRUIT.

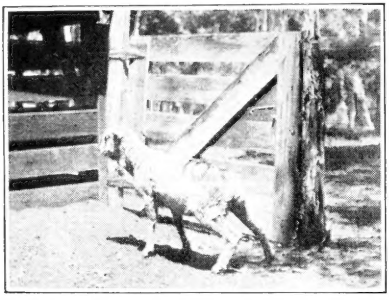

FIG. 1.—SHEEP 610. JULY 7, 1.20 P. M. WEAKNESS IN HIND LEGS, MORE PRONOUNCED ON ONE SIDE.

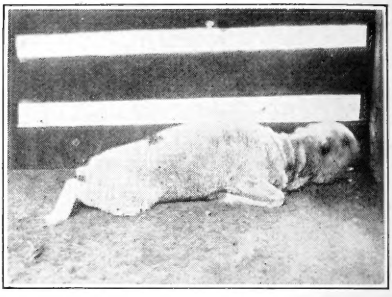

FIG. 2.—SHEEP 610. JULY 9, 4.05 P. M. POSITION AFTER FALLING.

FIG. 3.—SHEEP 610. JULY 9, 4.12 P. M. STANDING WITH DIFFICULTY.

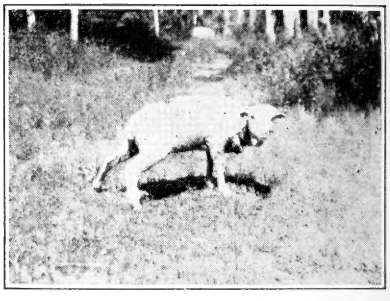

FIG. 4.—SHEEP 610. JULY 10, 9.50 A. M. A CHARACTERISTIC ATTITUDE WHEN ATTEMPTING TO STAND.

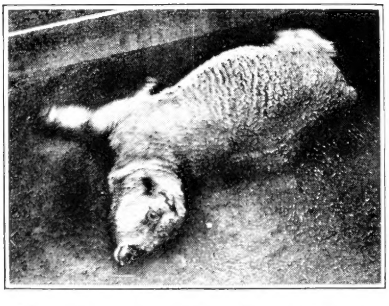

FIG. 5.—SHEEP 590. SEPTEMBER 1, 8.50 A. M. THE ANIMAL IN A SPASM IN OPISTHOTONOS POSITION.

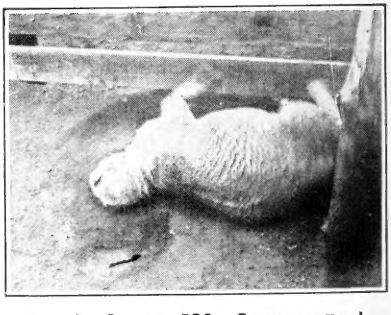

FIG. 6.—SHEEP 590. SEPTEMBER 1, 9.10 A. M. THE ANIMAL IN A SPASM.

TABLE 1.—*Summary of feeding experiments with Asclepias mexicana (air-dried plant fed with balling gun; no remedies used).*

Animal.		Date of feeding.	Part of plant used.	Weight of plant estimated as green plant per 100 pounds of animal.	Result.	Place and date of plant collection.
Designation.	Weight.					
	Pounds.	1920.		*Pounds.*		
Sheep 582	98	June 21	Leaves	0.176	Not sick	Mount Diablo, Calif., fall of 1919.
Sheep 588	93	June 23	do	.353	Sickness	Solano, Calif., fall of 1919.
Sheep 595	78	June 28	do	.529	do	Do.
Sheep 603	97.75	July 1	do	.705	do	Do.
Sheep 607	93	July 6	Stems	.705	Not sick	Do.
Sheep 610	81.75	do	Leaves	.882	Death	Do.
Sheep 563	102.5	July 8	Stems	.882	Not sick	Do.
Sheep 579	86	July 13	do	1.058	do	Do.
Sheep 581	75.5	July 14	do	1.323	Slight sickness	Mount Diablo, Calif. fall of 1919.
Sheep 584	82	July 16	do	1.411	Not sick	Do.
Sheep 586	128	July 20	do	1.764	Slight sickness	Mount Diablo and Solano, Calif., fall of 1919.
Sheep 595	81	July 22	do	1.481	Not sick	Solano, Calif., fall of 1919.
Sheep 568	86	Aug. 10	Leaves, stems, and flowers.	.882	Sickness	Newman, Calif., July, 1920.
Sheep 575	72.25	Aug. 13	Leaves, stems, and flowers. Large proportion of stems.	1.058	do	Do.
Sheep 580	69	Aug. 23	Leaves, stems, and flowers.	1.235	do	Do.
Sheep 590	103.5	Aug. 31	do	1.543	Death	Do.
Sheep 595	92	Sept. 3	do	1.323	do	Do.
Sheep 602	93.25	Sept. 9	Stems	2.205	Symptoms	Do.
Sheep 603	106.5	Sept. 13	do	3.527	Possible symptoms.	Do.

TYPICAL CASE, SHEEP 610.

Sheep 610 was a ewe weighing 81.75 pounds at the time of the experiment. She had not been used in any other experimental work. To this animal was given by the balling gun, between 5.07 and 5.15 p. m., on July 6, 87.75 grams of dry *Asclepias mexicana* leaves, an equivalent of 0.882 pound of green plant per 100 pounds of animal. When observed at 6.25 a. m. July 7 she was unsteady, staggering as she walked about. At 7.20 a. m. the unsteadiness had increased in a marked degree. At 8.59 a. m. her temperature was 105° F., pulse 152, respiration 36. When observed between 1.10 and 1.30 p. m. she could move about without falling, but staggered, and when moving about went with a sidling gait, the weakness being most pronounced in the hind legs. Plate II, figure 1, shows very clearly this weakness in the hind legs. This condition continued during the afternoon and evening. At 5.33 p. m. the temperature was 103, pulse 140, and respiration 44.

On July 8 at 8.30 a. m. she appeared somewhat better than on the preceding day. At 9.36 a. m. the temperature was 102.4, pulse 120,

respiration 40, the pulse being somewhat weak and irregular. During the day her condition remained very much the same, and at night she seemed to be somewhat stronger than in the morning.

On July 9 at 9.22 a. m. the temperature was 102.5, pulse 120, respiration 56. The pulse was rapid, weak, and regular. The animal still was weak and staggered, as in the preceding day. At 4.07 p. m. the sheep was watered, and while being brought in fell and was able to stand only with assistance. When placed in her pen she fell, coming down flat on the ventral surface, with her hind legs stretched out behind. (See Pl. II, fig. 2.) She was able soon to get upon her feet, but stood with difficulty, as shown in Plate II, figure 3. At 4.27 p. m. she was down again in the same position as shown in Plate II, figure 2. At 4.46 p. m. her temperature was 103, pulse 170, respiration 60. Respiration was irregular ,and she was unable to stand on her feet very long.

On July 10 at 9.03 a. m. the temperature was 102.1, pulse 140, respiration 80. During the day the animal continued much as on the preceding day, but apparently was somewhat stronger. At 9.45 in the morning she was taken out of the pen and placed in the yard, where she could get at grass, but ate very little. Plate II, figure 4, shows the attitude assumed by the animal. At 4.21 p. m. the temperature was 104.3, pulse 128, respiration 82. At 7.20 p. m. she suddenly fell in a spasm, drawing the head back in a position of opisthotonos and using the legs vigorously. She was unable to get upon her feet until 7.24 p. m., when she stood with legs spread apart, head low and stretched forward. At 7.27 p. m. she stepped back with her head held high, fell over on the left side, groaned, struck her head upon the ground repeatedly, then threw the head back in a clonic spasm followed by a tonic spasm. At 7.33 p. m. she was lying with head partly raised and shaking as if with palsy. At 7.34 p. m. she rose to her feet, but at 7.35 fell with the forefeet spread out. At 7.38 p. m. she was upon her feet again, and was able to stand in a very uncertain way, but was down again at 9.35 p. m., the mouth moving as if chewing. She was somewhat salivated at this time. At 10 p. m. she was still down, but with the head erect, moving from side to side. At 10.15 p. m. she was going through a series of clonic spasms. At 11 p. m. she was dead, having struggled more or less violently just before death.

No good pictures were taken of this animal during the period of spasms, but Plate II, figures 5 and 6, which were taken of Sheep 590, show some of the characteristic attitudes assumed by animals in the stage of spasms. Figure 5 shows very clearly, in the condition of the ground of the corral, how the animal when down goes through a series of motions. This animal differed somewhat from others in that at no time was there an extremely high temperature.

RESULTS OF EXPERIMENTAL WORK AND CONCLUSIONS.

SYMPTOMS.

The symptoms exhibited by poisoned animals paralleled very closely those seen in cases poisoned by the other whorled milkweeds, *A. galioides*, *A. pumila*, and *A. verticillata* var. *geyeri*, differing little except in degree.

There was depression with staggering, the weakness being especially marked in the hind legs. As in the *A. pumila* cases, while standing the animals frequently held the head rather high with the nose extended forward. The pulse was always high and rather weak. These were the only symptoms in the milder cases, if we except a slightly higher temperature.

In the severe cases the stage of weakness was followed by a stage in which there were spasms, mostly clonic, like those exhibited by animals poisoned by *A. galioides*. The animal would throw itself about violently, sometimes showing an opisthotonic position in its spasms, sometimes drawing the head toward the chest. Walking and running movements, while lying on the side, accompany the spasms, and frequently there are convulsive movements of the jaw. Two of the fatal cases were salivated and one was bloated. The animals groan, and in breathing there is frequently a marked interval between inspiration and expiration, the expiration being more or less violent. The temperature rises during the spasms. In Sheep 590 it reached 107.7° F. and in Sheep 595, 106.4° F. These maximum temperatures were taken just after the death of the animals. In this connection it is interesting to note that temperature observations on *A. galioides* showed a decline in temperature before death (Bul. 800, p. 26), while in the *A. mexicana* and *A. pumila* cases (Bul. 942, p. —) the maximum was reached at the time of death. In all whorled-milkweed cases the prognosis of those which pass into the stage of spasms is bad.

Only three of the *A. mexicana* cases showed spasms, and they died. Of the *A. galioides* cases described in Bulletin 800 only one, Sheep 478, recovered after passing into the stage of spasms. Of the sheep poisoned by *A. pumila* only two exhibited spasms, and they died. Only three sheep were poisoned by *A. verticillata* var. *geyeri;* all recovered, and two went into the stage of spasms.

DELAY IN DEVELOPMENT OF SYMPTOMS.

Table 2 shows the time which elapsed before the appearance of symptoms.

The average time of 14 hours and 5 minutes between the time of feeding and beginning of symptoms is probably slightly high. A few sheep showed symptoms when first seen in the morning and may have been sick for some time previously. Then, too, in cases which

come down somewhat slowly, as these do, it is not easy to distinguish the very beginning of symptoms. The shortest time was 12 hours and 45 minutes, occurring in three cases, and they were sick when first observed in the morning following the feeding.

TABLE 2.—*Time elapsed between feeding of plant and development of symptoms.*

Animal.	Quantity per 100 pounds of animal.	Part of plant used.	Result.	Time elapsing before symptoms.
	Pounds.			*H. m.*
Sheep 588	0.353	Leaves	Sickness	14 40
Sheep 595 (June 28)	0.529	do	do	14 45
Sheep 603 (July 1)	0.705	do	do	16 25
Sheep 610	0.882	do	Death	13 10
Sheep 581	1.323	Stems	Slight sickness	15 10
Sheep 586	1.764	do	do	15 37
Sheep 568	0.882	Leaves, stems, and flowers	Sickness	14 51
Sheep 575	1.058	do	do	12 45
Sheep 580	1.235	do	do	12 45
Sheep 590	1.543	do	Death	12 55
Sheep 595 (Sept. 3)	1.323	do	do	12 45
Sheep 602	2.205	Stems	Symptoms	12 50
Sheep 603 (Sept. 13)	3.527	do	do	13 49
Average				14 5

The time elapsing before symptoms in *A. galioides* was 14 hours and 6 minutes; in *A. pumila* 16 hours and 17 minutes; and in *A. verticillata* var. *geyeri* 16 hours and 47 minutes.

The average time in all the species of whorled milkweed was much the same. There was, however, much more variation in limits of time in the other species. *A. galioides* varied from $2\frac{1}{4}$ to 21 hours, *A. pumila* from 12 hours and 37 minutes to 30 hours and 15 minutes, and *A. verticillata* var. *geyeri* from 14 hours and 10 minutes to 20 hours and 35 minutes, while *A. mexicana* varied only from 12 hours and 45 minutes to 16 hours and 25 minutes.

A comparison of these figures with those in Fleming and co-authors (1920, pages 15 to 17), shows a good agreement in averages. In Table I on feeding of green plant the average time from feeding to symptoms was 15 hours and 27 minutes. The combined average of Tables II and III of feedings of dry plant was 14 hours and 48 minutes. This latter average is obtained on the assumption that the time of feeding of Sheep No. 8 was probably 2.50 p. m. instead of 2.50 a. m., as given in the Nevada bulletin.

There is, however, a wider range of variation than in the work at the Salina Experiment Station, the minimum being 1 hour and 50 minutes, and the maximum 23 hours and 20 minutes. The large maximum figures are doubtless explained, in part at least, as stated in the Nevada bulletin, by the fact that no night observations were made, so that in many cases the time of the beginning of symptoms was not noted. The minimum figures in most cases are correlated with very heavy doses.

DURATION OF SICKNESS.

Table 3 shows the length of time the sickness continued in cases which recovered. The times were computed from the first symtom noted to the last. The actual periods of illness doubtless were somewhat greater, for as the animals were not generally under constant observation neither the beginning nor the ending of sickness would be recorded with much accuracy. The figures, however, will give a good general idea of the duration of illness and can be compared with the results in the other whorled milkweeds, as they were obtained in the same manner.

TABLE 3.—*Duration of sickness in cases of recovery.*

Animal.	Duration of symptoms.	Animal.	Duration of symptoms.
	H. m.		*H. m.*
Sheep 588	50 10	Sheep 568	95 54
Sheep 595	48 20	Sheep 575	73 45
Sheep 603	48 1	Sheep 580	74 6
Sheep 581	7 30	Sheep 602	5 40
Sheep 586	7 54	Sheep 603	(1)

[1] One observation only.

Of the three animals that died, Sheep 610 was sick 89 hours and 35 minutes; Sheep 596, 14 hours and 56 minutes; and Sheep 595, 15 hours and 15 minutes.

The shortest period of illness was in Sheep 602—5 hours and 40 minutes—and the longest in Sheep 568—95 hours and 54 minutes. As in other whorled-milkweed cases the symptoms continued longest in the more pronounced cases.

The average period of sickness was 45 hours and 42 minutes.

It was shown in Bulletin 942, United States Department of Agriculture, pages 12–13, that the average period of sickness in sheep poisoned by *A. galioides* was 4 hours and 39 minutes; by *A. pumila* it was 48 hours; and by *A. verticillata* var. *geyeri* it was 56 hours.

It is evident that the period of sickness in the *A. mexicana* cases corresponded fairly well to that found for *A. pumila* and *A. verticillata* var. *geyeri*, and like them differed widely from the *A. galioides* cases.

In the experiments of Fleming and co-authors (1920) the average duration of sickness in the sheep that recovered, as given in Tables I, II, and III, was 39 hours and 37 minutes, while in the cattle as given in Tables VII and IX it was 34 hours and 1 minute.

AUTOPSY FINDINGS.

Autopsies were made upon the three animals that died. Two of the three were bloated. The lungs were congested in all. In two the thymus was congested, and in the third there were petechiæ in this organ. Petechiæ were present on the hearts of two.

In one animal congestion was present in the duodenum, jejunum, and ileum; in another this condition was found only in the ileum and cecum; while the third had a hemorrhagic area in the duodenum and minute hemorrhages in the ileum. The pancreas was congested in one. The livers of two were noted as pale. The kidneys were congested in one and hyperemic in another.

In general, the autopsy findings corresponded very well to those seen in animals poisoned by the other whorled milkweeds.

PATHOLOGICAL CHANGES IN TISSUES.

The autopsies in 2 of the 3 sheep killed with *Asclepias mexicana* in 1920 were commenced within 30 minutes after their deaths. These were Sheep 590 and 595. Sheep 610 was dead much longer before the autopsy and well-marked post-mortem changes had occurred in the tissues. The following description of the pathological changes is based on Nos. 590 and 595. The material was fixed in 10 per cent formalin and stained with Delafield's hematoxylin and eosin, except specimens of the cerebellum of Sheep 590, which were fixed in alcohol and stained with various nerve-cell stains. Formalin-fixed material of the cerebellum of both sheep was stained with toluidin blue, Nissl stain, polychrome methylene blue, neutral red, and other stains.

Liver.—The hepatic cells in both animals had undergone well-marked degenerative changes which differed slightly in the two cases—those of Sheep 590 were very fatty, the nuclei, however, taking the stain well, while the hepatic cells in the liver of Sheep 595 had a very granular and swollen cytoplasm. In the liver of Sheep 595, too, certain hepatic cells, singly and in groups, showed marked affinity for eosin. In the capillaries of the liver lobules of both there was an unusually large number of leucocytes, especially polymorphonuclear. These were often in small clumps, covering the area of half a dozen or more hepatic cells in the liver section of Sheep 590.

The livers of both animals had congested and edematous areas with some small hemorrhages. This was most noticeable in one preparation of the liver of Sheep 590, where the congestion was severe just beneath the capsule and had compressed the liver cords.

Many veins, both portal and hepatic, were empty, while others contained much granular detritus, brownish pigment granules, degenerate erythrocytes, and sometimes endothelial cell nuclei and numerous leucocytes. Rarely hepatic cells were found in the sublobular veins. The wall of the congested portion of the common bile duct in both cases had undergone necrotic changes extending well into the mucosa. The epithelial layer was gone.

Kidneys.—In both kidneys there was congestion of the straight veins of the medulla and areas of capillary congestion in the cortex with a few small hemorrhages betweeen the tubules. The principal

change had occurred in the epithelial cells of the convoluted tubules and consisted of cloudy swelling. Other cells were present, singly and in groups, the cytoplasm of which had an unusual affinity for eosin. Such cells contained shrunken nuclei which stained darker and more uniformly than normal. Other nuclei were very faint or had entirely disappeared. The lumina in may places contained a considerable quantity of disintegrated cytoplasm and sometimes free epithelial cell nuclei. In congested areas frequently epithelial cells of the tubules contained considerable brownish granular pigment. Granular material, pigment, and an abnormal number of leucocytes were found in some veins. Some distended capillaries in the sections from the kidneys of Sheep 595 were occupied by hyalin areas which stained strongly with eosin.

Other tubules than the convoluted, as the ascending limb of Henle, showed similar though less pronounced changes.

Heart.—The myocardium of the left ventricle showed changes like those occurring in some of the *A. galioides* cases, but were not so marked. In many areas the capillaries were distended with blood and very prominent between the muscle fibers. The tissue was mildly edematous. In most areas the muscle fibers had a less distinct cross-striated appearance and a more granular cytoplasm than normal. A few minute hemorrhages appeared. Very few leucocytes were present. The red blood corpuscles stained well and appeared to be normal.

Lungs.—There was a mild inflammation of the lungs. The capillaries were engorged and distended, in many places nearly filling the alveoli. Numerous leucocytes, mostly polymorphonuclear, were scattered throughout the tissue. Many epithelial cells of the alveoli appeared swollen or vacuolated and their nuclei were irregular in outline. The epithelial cells of the bronchioles were swollen or in the process of disintegration, the bronchioles containing much granular material, many nuclei of exfoliated cells, and sometimes erythrocytes.

In some veins there were areas composed of normal and pale erythrocytes, much finely granular material, and a considerable number of leucocytes, mostly polymorphonuclear. A considerable quantity of brownish pigment was distributed throughout the sections.

Thyroid.—Little that was abnormal was found in the thyroid glands. This organ was not congested in either animal, though some brownish pigment and pale erythrocytes were found. In a few capillaries the erythrocytes appeared to have fused, forming hyalin thrombi. In the *A. galioides* cases this gland was almost always severely congested.

Thymus.—Congestion had occurred in the thymus in each of the two sheep, though this was most pronounced in the thoracic portion of the gland of Sheep 595, where extensive hemorrhage into the

glandular tissue had occurred, especially into the medullary portion of the lobules. Around some blood vessels in the thymus of Sheep 595 there were many large, coarsely granular cells, which had a strong affinity for eosin. These closely resembled eosinophiles, except that many were rather large and had nuclei almost circular in outline. The lymphoid cells appeared to be normal. Some brownish pigment was present, and in a few small veins in Sheep 590 the erythrocytes appeared as though fused.

Spleen.—In the specimen from the spleen of Sheep 590 there were small areas of congestion in the splenic pulp. The samples from Sheep 595 contained very little blood. In both cases some brownish pigment was present, and in the tissue from Sheep 590 some cavernous veins contained pale and disintegrated erythrocytes.

Lymph glands.—A mesenteric lymph gland and a small group of hemolymph nodes from Sheep 590 were studied. There was no indication of an effect on lymphoid cells, but some erythrocyte destruction was apparent. In the lymph gland many endothelial cells contained ingested erythrocytes in various stages of destruction. In the hemolymph nodes there were areas where practically all erythrocytes stained very poorly.

Alimentary tract.—Specimens from the abomasum, duodenum, jejunum, ileum, and cecum were studied. There was a well-marked infiltration of leucocytes into the mucosa of the various portions of the small intestine and the one sample of cecum examined. These were of the polymorphonuclear and plasma cell types. Congestion accompanied with diapedesis of erythrocytes and edema was present in some places, and in all portions of the small intestine the villi and that portion of the mucosa next the lumen of the intestine were more necrotic than one would expect in an animal that had been dead so short a time.

The glandular epithelial cells were swollen and many small nuclei, probably of leucocytes, were very commonly lying in the epithelial layer and sometimes in the lumen of the gland. Many such nuclei were degenerated. In places the veins contained pale erythrocytes, granular material, and sometimes a fibrinlike network and numerous leucocytes.

The lymph nodes of the ileum of Sheep 590 were edematous and contained an unusual number of phagocytic cells, which had ingested erythrocytes and pigment or partially digested granules of nuclear material.

Nervous tissue.—Specimens of cerebrum, cerebellum, medulla, and cervical and lumbar portions of the spinal cord were examined. None of these was severely congested, though minute hemorrhages were formed in various places. These were presumably due to diapedesis of the red corpuscles, as ruptured vessels were not found. In most hemorrhages the erythrocytes were confined to the perivascular

lymph space, but in some instances they had penetrated into the surrounding tissue. Pericellular lymph spaces, in many if not most instances, were enlarged. The nerve cells had undergone fatigue changes similar to those found in the *A. pumila* and *A. galioides* cases. This consisted in a breaking up of the Nissl bodies or a marked reduction in the chromatin content of the cell.

In general the pathological conditions of the *A. mexicana* cases are the same as those found in *A. galioides* and *A. pumila* poisoning, and consist mainly of capillary congestion and degenerative changes in certain tissues. Areas of congestion were found in the liver, kidneys, heart, muscle, lungs, thymus, and mucosa of portions of the intestines. The cells of the liver, kidney tubules, heart muscle, intestinal glands, and certain nerve cells showed degenerative changes which may probably be accounted for by excessive functional activity. Fatigue effects were most apparent in the heart-muscle fibers and nerve cells. The presence of an abnormal number of leucocytes in the liver, intestinal mucosa, and lungs is probably due to the degenerative changes of the tissue cells.

Degeneration of hepatic cells, epithelium of kidney tubules, and intestinal mucosa appears to be more pronounced in the *A. mexicana* cases than in those animals killed by *A. galioides*. On the other hand the degeneration and capillary congestion of heart muscle, congestion of the nervous system, and fatigue effects on the Purkinje cells of the cerebellum were much more pronounced in the *A. galioides* cases.

The changes found in the tissues of the *A. pumila* cases correspond very closely to those described for the *A. mexicana* cases. The effects of these two species of plants would appear to be practically the same, but those produced by the more toxic *A. galioides* differ slightly in degree.

TOXIC AND LETHAL DOSES.

The balling gun was used in all the experimental work from which the dosage was computed, so that the animals probably received the material in a somewhat shorter time than they would when feeding on the range. It would be expected on this account that under range conditions the dosage, in the majority of cases, would be larger.

Whole plant.—Table 4 shows the dosage when the animals received the whole plant.

TABLE 4.—*Dosage of A. mexicana, whole plant.*

Animal.	Quantity fed per 100 pounds of animal.	Result.	Animal.	Quantity fed per 100 pounds of animal.	Result.
	Pounds.			*Pounds.*	
Sheep 568	0.882	Sickness.	Sheep 590	1.543	Death.
Sheep 575	1.058	do.	Sheep 595	1.323	Do.
Sheep 580	1.235	do.			

The minimum lethal dose for these animals was 1.323 pounds. This is probably a rather accurate figure, for Sheep 575 received 1.058 pounds and Sheep 580 1.235 pounds without fatal results in either case. The minimum toxic dose was 0.882 pound. No experiments were made with slightly smaller doses, but as Sheep 568 was a mild case this dose must be not far from the minimum of toxicity.

Leaves.—Table 5 shows the dosage when leaves only were fed.

TABLE 5.—*Dosage of A. mexicana, leaves only.*

Animal.	Quantity fed per 100 pounds of animal.	Result.	Animal.	Quantity fed per 100 pounds of animal.	Result.
	Pounds.			*Pounds.*	
Sheep 582	0.176	Not sick.	Sheep 603	0.705	Sickness.
Sheep 588	0.353	Sickness.	Sheep 610	0.882	Death.
Sheep 595	0.529	do.			

As Sheep 603 was not very sick on 0.705 pound, it is probable that 0.882 pound, which caused the death of Sheep 610, is close to the lethal dose. While 0.353 pound was the smallest dose producing sickness, it is possible that it is not the minimum, as there were no tests between that and 0.176 pound which was given without effect to Sheep 582.

Stems.—Nine sheep were fed on stems from which all leaves had been removed, as shown in Table 6.

TABLE 6.—*Dosage of A. mexicana, stems only.*

Animal.	Quantity fed per 100 pounds of animal.	Result.	Animal.	Quantity fed per 100 pounds of animal.	Result.
	Pounds.			*Pounds.*	
Sheep 607	0.705	Not sick.	Sheep 586	1.764	Slight sickness.
Sheep 563	0.882	do.	Sheep 595	1.481	Not sick.
Sheep 579	1.058	do.	Sheep 602	2.205	Symptoms.
Sheep 581	1.323	Slight sickness.	Sheep 603	3.527	Possible symptoms.
Sheep 584	1.411	Not sick.			

The smallest quantity of stems fed which produced symptoms was 1.323 pounds. As compared with this, Sheep 584 and Sheep 595 showed no effect from 1.411 pounds and 1.481 pounds, respectively. The table shows also that as much as 3.527 pounds was fed to Sheep 603 with only slight effect. No animals were killed by the feeding of stems. It appears then that as little as 1.323 pounds may produce slight symptoms. The lethal dose has not been determined, but it probably is several times this quantity.

For comparative purposes the toxic and lethal doses of whole plant, leaves, and stems to 100 pounds of animal may be tabulated as follows:

	Minimum toxic dose.	Minimum lethal dose.
	Pounds.	*Pounds.*
Leaves	0.353	0.882
Whole top	0.882	1.3
Stems	1.323	More than 3.5

It is evident that the toxic principle of the plant is found very largely in the leaves.

A comparison of the preceding figures with the toxic and lethal dosages for sheep given in Nevada Bulletin 99 can be made by reducing the dosage in Table I, page 15, of the Nevada bulletin to pounds per hundredweight of animal. It will be seen that the smallest toxic dose, 0.537 pound per hundredweight in the case of Sheep 25, is somewhat smaller than the figures obtained in our experiments. It may be noted, too, that Sheep 75 received 0.555 pound without effect and that the smallest lethal dose was 2.3 pounds in the case of Sheep 6.

If the data of Table II of the Nevada bulletin giving the feedings of air-dried plant are similarly reduced to a dosage for 100 pounds of animal and an allowance of a loss of 75 per cent by evaporation is made, as in our work, the smallest lethal dose would be 2.059 pounds in Sheep 72 and the smallest toxic dose 1 pound in Sheep 59.

The dosage in Table III (Nevada) of material which had dried in the field is somewhat larger, the lethal dose, 7.5 pounds in Sheep 43, being especially large. This is probably accounted for by the fact that there had been some loss of leaves in the field, for it is shown on page 14 of this paper that the leaves are especially toxic.

Table 7 shows the comparative toxicity of the different whorled milkweeds:

COMPARATIVE TOXICITY OF SPECIES OF WHORLED MILKWEED.

TABLE 7.—*Comparative toxicity of different species of whorled milkweed.*

Species.	Minimum toxic dose of whole plant.	Minimum lethal dose of whole plant.	Minimum toxic dose of leaves.	Minimum lethal dose of leaves.	Minimum toxic dose of stems.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
A. mexicana	0.882	1.323	0.353	0.882	1.323
A. galioides	0.22	0.22	0.138	0.138	1.543
A. pumila	0.787	2.165	.....	.....	.....
A. verticillata var. geyeri	2.205	.....	1.286	.....	.....

While too much reliance must not be placed on this table as showing exact relationships, nevertheless it indicates, in a general way, the relations between the species. So far as the whole plant is concerned, *A. mexicana* and *A. pumila* are about equally toxic. *A. galioides* is 4 times as toxic as these two species and 10 times as toxic as *A. verticillata* var. *geyeri*. As regards the lethal dose of the whole plant, *A. galioides* is 6 times as toxic as *A. mexicana* and 9.84 times as toxic as *A. pumila*.

With relation to the leaves, *A. galioides* and *A. verticillata* var. *geyeri* compare much as in the whole plant; that is, in a ratio of about 1 to 10. The ratio of *A. galioides* to *A. mexicana*, however, is 1 to 2.56 instead of 1 to 4, as in the whole plant, while the lethal dose is in

the ratio of 1 to 6. There is an apparent anomaly in the dosage of the stems in that the much more poisonous *A. galioides* requires a slightly larger dose than *A. mexicana*. This may be explained in part by the fact that the stems of both plants are only slightly toxic, but there is also some reason for thinking that the chemical study of these plants, the results of which will be published later, will offer an adequate explanation.

ANIMALS AFFECTED.

The experiments reported in this bulletin were on sheep only. Fleming and his co-authors (1920) have shown that cattle are poisoned with a somewhat similar dosage. From the fact that *A. mexicana* produces effects strictly comparable with those caused by *A. galioides* and that it has been shown in a previous paper (U. S. Department of Agriculture Bulletin 800) that *A. galioides* poisons horses as well as sheep and cattle, it is fair to conclude that *A. mexicana* will have the same effect.

SUMMARY.

Asclepias mexicana (the Mexican whorled milkweed), a plant growing on the Pacific slope, and especially in California and Nevada, has long been considered a stock-poisoning plant, particularly dangerous to sheep; but there has not been definite knowledge of the symptoms produced by it or of its toxic dosage.

It produces effects very similar to those produced by the other whorled milkweeds, *A. galioides*, *A. pumila*, and *A. verticillata* var. *geyeri*.

In toxicity *A. mexicana* is about equal to *A. pumila* and about one-fourth as toxic as *A. galioides*. The lethal dose is six times that of *A. galioides*, but about one-half that of *A. pumila*.

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